MODELING SIGNAL BLOCK IN LEECH NEURONS

Richard Gejji[1], A. Scott Patterson[2], Dr. Carl Cowen*[2], Sashi Marella[2]
Kalamazoo College[1], 1000 Academy St., Kalamazoo, MI 49006
Purdue University[2], 150 N. University St., West Lafayette, IN 47907
apatters@purdue.edu

A firing neuron emits a signal that travels through its axon to a synapse. This signal, known as an action potential, is typically thought of as an all or nothing phenomenon. Either the signal is strong enough to propagate through the entire axon, or it is not. In some situations the action potential is more dynamic and can block or reflect at certain points in the axon. These blocking and reflecting phenomena have been observed at points in the axon that exhibit a decrease in conductance: branch points and points of diameter increase. Mathematical theory can explain why action potentials will always block or reflect at these points of conductance change. However, experimental observations of touch-cell neurons in the medicinal leech undergoing repetitive stimulus, will initially exhibit normal action potential transmission. Over time they will go in and out of block and reflect states. More than a simple conductance change in the leech touch-cell axon must be present to explain this seemingly stochastic nature of the action potential propagation.

We present a model of the leech touch-cell axon in which the extra-cellular space is confined and ion concentrations are allowed to accumulate. This allows for a buildup in charge outside the axon, resulting in a block or reflection. The slow diffusion of the ions in the extra-cellular space will eventually bring the axon back to a normal transmission state. There is evidence that the axons of the leech touch-cells are surrounded by a 150 Å extra-cellular space and the model demonstrates that this is enough to force the touch-cell axons into and out of block and reflection states. The results are similar to the experimental observations and offer insight toward the biological cause behind the dynamic behavior of action potentials in a leech touch-cell under repetitive stimulus.

In our talk we will present a brief background of the central nervous system of a medicinal leech. Followed by an overview of observed phenomena in the axon of a leech touch-cell. Then the model and the basis for its construction will be explained. We will conclude with experimental and theoretical results regarding the accuracy of the hypothesis that confined extra-cellular space causes the dynamic action potential behavior seen in the axon of a leech touch-cell under repetitive stimulus.

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